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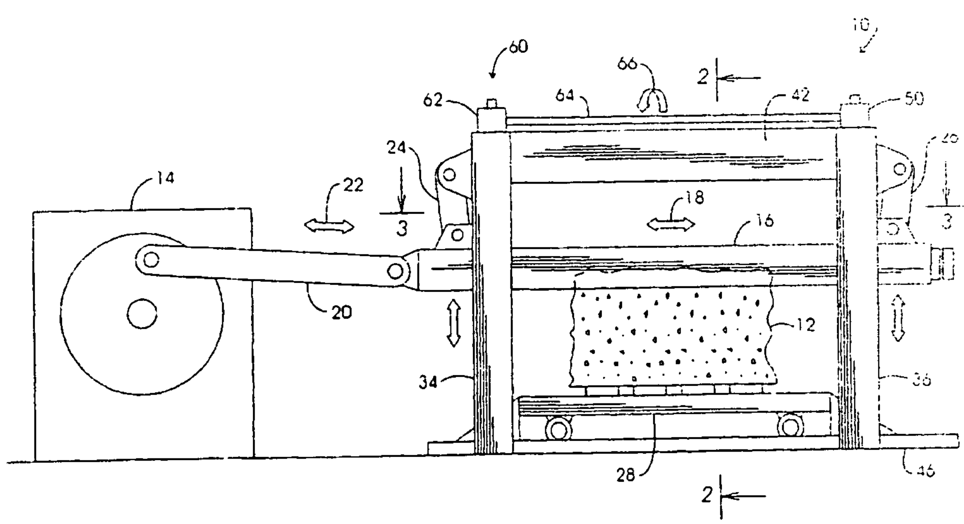

(57) Abstract: A horizontal frame saw (10) is equipped with a plurality of generally parallel, spaced-apart blades (88) for cutting granite (12). Each of the blades (88) has a cutting edge with diamond cutting segments (92) mounted thereon for engaging the granite (12) with a swinging motion for cutting of the granite (12).

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METHOD AND APPARATUS FOR CUTTING GRANITE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of provisional application 60/139,654, filed on June 17, 1999, the disclosure of which is expressly incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to an apparatus and method for cutting slabs of granite.

BACKGROUND OF THE INVENTION

Swing-type frame saws have been used commonly for cutting large granite blocks into slabs. These frame saws employ up to 250 steel blades mounted under tension (*e.g.*, 80 kN) on a frame. The frame typically swings about two pivot points. In order to cut granite, the steel blades work together with a slurry containing steel shot and lime dispersed in water. Maximum cutting speeds of 3 cm/hour make this technique slow. For example, cutting a 2-m high block of granite at 3 cm/h downfeed takes almost three days. Both the steel shot process and the time requirements for cutting granite are reasons for the consumption of large amounts of environmentally hazardous steel shot/water/lime slurry. The steel blades also have a useful life of 2-3 blocks on average, which contributes to the costs involved in cutting granite.

U.S. Patent No. 4,474,154 describes a sawing machine with a triangular straight prism shape frame mounted for pivoting around a horizontal axis with two saw blades. For cutting granite, blades are described as "steel ones, sprinkled with water and abrasive grits (like sand, steel shot or silicon carbide) either ones with diamond segments. Other patents relating to saws include U.S. Patents Nos. 3,760,789; 2,951,475; 5,150,641; 5,087,261; 5,080,085; 3,554,197; 2,247,215; and 337,661.

SUMMARY OF THE INVENTION

A horizontal frame saw for cutting granite has a plurality of adjacent and spaced-apart blades for cutting granite. Each of the blades includes diamond cutting segments mounted on a cutting edge thereof for engaging granite with a swinging type motion for cutting slabs of granite.

A method for cutting granite with a horizontal frame saw having a plurality of adjacent and spaced-apart blades for cutting granite is disclosed. Each of the blades include diamond cutting segments mounted on a cutting edge thereof for engaging the granite with a swinging type motion for cutting slabs of granite.

A saw blade for a granite-cutting horizontal frame saw having a plurality of adjacent and spaced-apart blades for cutting granite wherein includes diamond cutting segments mounted on a cutting edge thereof for engaging granite with a swinging type motion for cutting slabs of granite.

Advantages of the present invention include the elimination of conventional steel shot slurries heretofore used in cutting granite with horizontal frame saws. Another advantage is that the diamond-segmented steel blades can be refurbished with new diamond-containing segments after the original diamond segments are worn, and, thus, the steel blades can be re-used many times. A further advantage in using the diamond segments is the expected substantial increases in cutting rates, which may be on the order of at least 2-3 times. Yet an additional advantage is that the use of diamond segmented saw blades in cutting granite with a horizontal frame saw minimizes, if not overcomes, most cut deviations which plague conventional steel blades used with steel shot slurries. These and other advantages will be readily apparent to those skilled in the art based on the present disclosure.

DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic side-elevational view of a frame saw cutting through a granite block;

Fig. 2 is sectional view taken along line 2-2 of Fig. 1;

Fig. 3 is sectional view taken along line 3-3 of Fig.1;

Fig. 4 is sectional view taken along line 4-4 of Fig. 3;

Fig. 5 is sectional view taken along line 5-5 of Fig. 4;

Fig. 6 is a cut-away sectional view of the saw blade and diamond segments; and

Fig. 7 is sectional view taken along line 7-7 of Fig. 6.

The drawings will be described in detail below.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The diamond segments that are attached to the cutting edge of Steel blades used in conventional swing-type steel shot frame saw applications are sintered powder metallurgy segments. That is, diamond crystals are mixed with one or more metal powders or metal alloy powders, cold-pressed into the desired shape, and then sintered, optionally under pressure. A wide variety of metal powders and alloys can be used in forming diamond segments useful in practicing the present invention, as those skilled in that art will appreciate. Exemplary such metal and alloy powders include, for example, Ni, Cu, Fe, Co, Sn, W, Ti, or an alloy thereof, *e.g.*, bronze, and the like, optionally with ceramic and cermet powders added thereto, such as, for example, WC powder.

In an attempt to improve grit retention, the art coats the diamond particles with carbide-forming transition metals, such as, for example, Mo, Ti, and Cr. Such metals typically are chemically vapor deposited (CVD) or sputtered onto the surfaces of the diamond grit. Examples of such coatings and processes for the deposition thereof are disclosed in U.S. Patents Nos. 3,465,916, 3,650,714, 3,879,901, 4,063,907, 4,378,975, 4,399,167, and 4,738,689; U.S. Reissue No. 34,133; and EP-A79/300,337.7. It has been reported, however, that these coatings may be oxidized and, depending upon the carbide formed, may be brittle. In response, proposals have been made to use a carbide-forming metal layer as part of a multi-layer coating system. As is described in U.S. Patents Nos. 3,929,432, 5,024,680, 5,062,865, and 5,232,469, such multi-layer coating systems generally involve the vapor-phase deposition of an inner layer of a thin (0.05 to 15 micron thick) carbide-forming metal, and an outer layer of a more corrosion resistant metal, such as Ni or Cu, for protecting the inner layer from oxidation. Newer coating systems appear in the art periodically and similarly can be used to advantage in the present invention.

For purposes of the present invention, then, use of any and all technology related to the manufacture of diamond segments can be practiced to advantage in the cutting of granite with swing-type saw assemblies whose blades have cutting edges fitted with such diamond segments. In this regard, diamond particle sizes used in manufacturing diamond segments useful in the cutting of granite can range from about 15 mesh to 400 mesh (*e.g.*, as large as about 15/20 mesh diamond to as small as about 240/270 mesh diamond), with diamond particle sizes of between about 25/30 mesh and 70/80 mesh being presently preferred.

The grade of diamond grit refers internally to its crystalline structure and externally to its degree of symmetry in shape and surface smoothness. Higher grade diamond particles or grit is a crystalline structure containing very few imperfections (occlusions), is more symmetrical in shape, has a smoother external surface, and is expect to have a higher mechanical strength. Lower grade diamond usually has more occlusions, is not as symmetrical in shape and has a rougher external surface. Testing has revealed that all grades of diamond grit appear to function efficaciously in the cutting of granite.

The concentration of the diamond in the diamond segments can range from as low as about 10% by weight on up to about 50% by weight or higher. Present testing has revealed that lower ranges of diamond concentration (*e.g.*, about 10%-15% by weight) appear to enhance cutting performance of granite.

The diamond segments can range in dimension from about 5 to 100 mm in length by about 5 to 30 mm in height by about 4 to 8 mm in thickness, with segments of about 20 mm length by about 11.5 mm in height by about 6 mm in thickness presently being preferred. The diamond segments should be thicker than the thickness of the blade. The diamond segments can have any convenient shape including, for example, rectangular, tapered, sandwich, *etc.*

Spacing of the diamond segments along the blade edge can be essentially continuous (*e.g.*, 20 mm center-to-center for a 20 mm length diamond segment) on up to about 400 mm (center-to-center) or more, depending, of course, on the stroke length of the particular swing-type saw. For the 20 mm by 11.5 mm by 6 mm diamond segments reported in the Examples, 85 mm center-to-center spacing is being used.

The diamond segments are attached to the blade edge of the saw blades by brazing, which is the typical method for attachment of diamond segments to metal tools and parts. Such diamond segment brazing operation is conventional and well known in this art. Of course, such brazing operation must be conducted under conditions (*e.g.*, temperature) preclusive of appreciably damaging the diamond crystals in the diamond segment to such an extent that they suitability in the granite cutting/slabbing operation is compromised. Too, the temperature during the brazing operation also must not damage the blade or otherwise comprise its integrity and suitability for cutting granite.

Referring now to the swing-type frame saw itself, Fig. 1 is schematic side-elevational view of frame saw 10 cutting through granite block 12. Swing frame saw 10 is powered by motor 14, whose rotational movement is translated into horizontal movement of blade frame assembly 16 (see arrow 18) through arm 20

(see arrow 22). Blade frame assembly 16 retains a plurality of saw blades (to be described below) which cut slabs of granite from granite block 12. Blade frame assembly 16 is mounted to frame saw 10 by pivot arm assemblies 24, 26, 28 and 30 (see also Figs. 2 and 3), which, when powered by motor 14, moves in a swinging motion to cut granite block 12 with the plurality of saw blades mounted therewithin. Blade frame assembly, and consequently the blades retained thereby, typically have swing-radius of about 1-2 m. The "stroke" or swing-amplitude in most swing-type frame saws is between 0.4 and 1 m. Granite block 12 is conveyed into a cutting station and away therefrom by wheeled cart 32. Cart 32 also carries block 12 while it is being sawed.

Pivot assemblies 24-30 are carried by four vertical posts, 34, 36, 38, and 40 (see Figs. 1-3), respectively. These vertical posts are connected at their upper ends by beams 42, 44 (see Fig. 2), and two other beams not shown in the drawings. Vertical posts 34-40 are mounted to base platform 46 upon which cart 22 drives to place block 12 in the cutting station for its cutting.

Affixed to vertical posts 36 and 38 is downfeed assembly 48, which consists of motor 50, which rotates shafts 52 and 54, which rotate according to arrows 56 and 58. Affixed to vertical posts 34 and 40 is downfeed assembly 60 which consists of motor 62 and a pair of rotating shafts (not shown in the drawings). Motors 50 and 62 are synchronized by rotating shaft 64 that rotates in the direction of arrow 66. This synchronization ensures that blade frame 16 will be fed downwardly in a horizontal plane for even cutting of granite block 12. Shafts 52 and 54 are connected, respectively, to gear assemblies 68 and 70 which provide rotation as shown by arrows 72 and 74 to threaded rods 76 and 78, respectively. A similar arrangement (not shown in the drawings) exists for downfeed assembly 60. Threaded rods 76 and 78, in turn, carry pivot assemblies 26 and 28 with pivot assemblies 24 and 30 being carried by similar threaded rods disposed within vertical posts 34 and 40. The downfeed rate of blade frame 16 is determined by the speed of motors 50 and 62, which can be controlled by a feedback loop that senses the rate of cutting of granite block 12. The swinging motion or arc of blade frame 16 is shown by arrows 80 and 82 in Fig. 3.

Finally, the plurality of blades held by blade frame 16 are tensioned by hydraulic cylinder assemblies, such as illustrated by cylinder assembly 84, and by tensioning assembly 86, in Fig. 4. Due to the close spacing of the blades in blade frame 16, often adjacent blades are connected to cylinders which are alternatingly disposed at higher and lower vertical elevations. Of importance, however, is steel blade 88, which is representative of the plurality of blades

retained by blade frame 16. Mounted along the lower cutting edge of blade 88 are diamond segments 90-104, which can be greater or lesser in number than the eight illustrative segments depicted in Fig. 4. Such diamond segments permit much-improved cutting of granite, as will be exemplified in the Example, which follows this description of the invention. The retention of blade 88 within blade frame 16 is illustrated in Fig. 5.

An enlarged view of segments 90 and 92 is illustrated in Fig. 7. Fig. 8 illustrates that the segments are wider than the width of blade 88. Depending upon the thickness of blade 88, diamond segments 90-104 can range in thickness from about 2 to 8 mm. Blade 88 will have a height that ranges from about 50 to 500 mm and usually is rectangular in shape; although, hour-glass (double concave), convex/straight, concave/straight, double convex, and convex/concave, and like shapes are possible. A distinct advantage of the present invention is that steel blades used in conventional swing-type steel shot frame saw applications can be retrofitted with diamond-containing segments in order to cut/slab granite.

While the invention has been described with reference to a preferred embodiment, those skilled in the art will understand that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. In this application all units are in the metric system and all amounts and percentages are by weight, unless otherwise expressly indicated. Also, all citations referred herein are expressly incorporated herein by reference.

EXAMPLE

A swing-type Barsanti granite frame saw with twenty-five sets of 2 to 14 blades each was tested in class 3/4 granite (Rosa Sardo). The test demonstrated the ability to saw granite with a swing-type gang saw using diamond segments. All 25 sets of two to 14 blades cut into the granite. A maximum depth of cut of 1,200 mm was achieved. A downfeed of 6.5 cm/h (the machine maximum downfeed rate) was possible as compared to 3 cm/h max for a steel shot operation.

According to the test details, 25 sets of two to fourteen blades each were prepared according to DOE specifications. Factors were crystal grade (Grade 970 to Grade 920), size (25/30 mesh to 70/80 mesh), concentration (5 conc. to 50 conc.), coated vs. uncoated crystals, segment bond (15% Bronze (80/20 Cu/Sn) in coarse cobalt, 100% coarse cobalt, 5-50% WC in fine cobalt), number of segments (15 – 40), saw blades (dimensions 3.7 m long x 5 mm thick x 100 mm high, and 3.85 m long x 3.5 mm thick x 180 mm high), and blade tension (80 kN and 100 kN). Centerpoints and extreme conditions were included in the test. Segments (dimensions 6 mm x 20 mm x 11.5 mm) were prepared and brazed to the steel saw blades. The segments were distributed with even pitch, as well as with uneven pitch, resulting in an effective cutting length of 3 m. The granite cut was class 3/4 Rosa Sardo (dimensions: 2.85 m length x 1.8 m height x 2 m width, planar top surface to create equal conditions for each cut). The saw used was a swing-type, steel shot granite gang-saw (Barsanti) at Tirrenia Marmi, Italy, operating at 72 cycles per minute with a 440 mm stroke. These operation conditions result in an average cutting speed of 1.1 m/s (with a maximum around 2 m/s). The blades were tensioned to approx. 80,000 N.

Each trial run was started with slow a downfeed (1 - 3 cm/h) until all the segments were fully engaged in the block (1-3 hours). The downfeed then was increased to 4 - 6.5 cm/h until some segments were worn.

The evaluation was performed with a representative number of segments of each blade, which were measured to determine segment wear. These segments were kept for detailed evaluation. The "depth of cut" was measured at 3 points (front, center, and back) in each cut. The waviness of each cut was evaluated. This waviness was due to vibrations in the initial phase of the cutting until a cut was established and all segments were engaged (first ~10 mm of cut).

The depth of cut by the segments and the segment wear were measured, and wear performance (WP) was calculated. Analysis of the WP results indicated the following:

- diamond concentration is a significant WP factor with a higher concentration providing better wear performance;
- coating of the diamond crystals used to form the diamond segments also seems to be a significant factor for WP; and
- size and grade are less significant factors for WP.

Under extreme conditions:

- very high diamond concentrations (*i.e.*, > 50 conc.) prevented bond wear and enabled the deepest cuts (1200 mm), but cut deviation was significant (outside specification limit); and
- very low diamond concentrations (*i.e.*, < 10 conc.) resulted in the straightest cuts (*i.e.*, no cut deviation), but segment wear was significant such that the segment was spent after 1200 mm cut depth

Vibrations during beginning stages of cut increase the segment wear.

Steel blades can be refurbished with diamond containing segments after they are worn and, thus, can be used many times. In addition, the use of diamond segments provides possibly substantial increases in cutting rates, improvements may be on the order of at least 2-3 times, possibly even up to 50 cm/h. The resulting slabs can be cut within desired specification limits.

WHAT IS CLAIMED IS:

1. A horizontal frame saw equipped with a plurality of generally parallel, spaced-apart blades for cutting granite, wherein each of the blades has a cutting edge with diamond cutting segments mounted thereon for engaging the granite with a swinging motion for cutting of the granite.

2. The horizontal frame saw of claim 1, wherein said blades have a width and said diamond cutting segments have a width, the width of the said diamond cutting segments being greater than the width of said blades.

3. The horizontal frame saw of claim 1, wherein said diamond cutting segments are comprised of diamond particles bonded together by a metal or alloy.

4. The horizontal frame saw of claim 3, wherein said metal or alloy is one or more of Ni, Cu, Fe, Co, Sn, W, Ti, or an alloy thereof.

5. The horizontal frame saw of claim 3, wherein said diamond particles are coated with one or more of Mo, Ti, Cr, or alloys thereof.

6. The horizontal frame saw of claim 5, wherein said metal coated diamond particles are overcoated with one or more of Ni, Cu, or alloys thereof.

7. The horizontal frame saw of claim 3, wherein said diamond particles range in size from about 15 mesh to 400 mesh.

8. The horizontal frame saw of claim 7, wherein said diamond particles range in size from about 25/30 mesh to 70/80 mesh.

9. The horizontal frame saw of claim 3, wherein said diamond cutting segments contain between about 10% and 50% by weight of said diamond particles.

10. The horizontal frame saw of claim 9, wherein said diamond cutting segments contain between about 10% and 15% by weight of said diamond particles.

11. The horizontal frame saw of claim 1, wherein said diamond cutting segments range in size from about 5 to 100 mm in length by 5 to 30 mm in height by 4 to 8 mm in thickness.

12. The horizontal frame saw of claim 1, wherein said diamond cutting segments range in spacing from being in edge-to-edge contact to about 400 mm center-to-center.

13. The horizontal frame saw of claim 1, wherein said diamond cutting segments are brazed onto the cutting edge of said blades.

14. A method for cutting granite with a horizontal frame saw having a plurality of adjacent and spaced-apart blades wherein said blades have a cutting edge for engaging said granite for its cutting, which comprises engaging the granite with the cutting edges of said blades, wherein each of the blades includes diamond cutting segments mounted on the cutting edge thereof.

15. The method of claim 14, wherein said blades are provided with a width and said diamond cutting segments are provided with a width, the width of the said diamond cutting segments being greater than the width of said blades.

16. The method of claim 14, wherein said diamond cutting segments are formed from diamond particles bonded together by a metal or alloy.

17. The method of claim 16, wherein said metal or alloy used to form said diamond cutting segments is one or more of Ni, Cu, Fe, Co, Sn, W, Ti, or an alloy thereof.

18. The method of claim 16, wherein said diamond particles are coated with one or more of Mo, Ti, Cr, or alloys thereof.

19. The method of claim 18, wherein said metal coated diamond particles are overcoated with one or more of Ni, Cu, or alloys thereof.

20. The method of claim 16, wherein said diamond particles are provided in a size range of from about 15 mesh to 400 mesh.

21. The method of claim 20, wherein said diamond particles are provided in a size range of from about 25/30 mesh to 70/80 mesh.

22. The method of claim 16, wherein said diamond cutting segments are proved as containing between about 10% and 50% by weight of said diamond particles.

23. The method of claim 22, wherein said diamond cutting segments are provided as containing between about 10% and 15% by weight of said diamond particles.

24. The method of claim 27, wherein said diamond cutting segments are provided in a size range of from about 5 to 100 mm in length by 5 to 30 mm in height by 4 to 8 mm in thickness.

26. The method of claim 27, wherein said diamond cutting segments are provided with a spacing ranging from being in edge-to-edge contact to about 400 mm center-to-center.

27. The method of claim 14, wherein said diamond cutting segments are brazed onto the cutting edge of said blades.

28. A saw blade for a horizontal frame saw equipped with a plurality of generally parallel, spaced-apart blades for cutting granite, said saw blade having a cutting edge, which has diamond cutting segments mounted thereon for said diamond cutting segments to engage granite with a swinging type motion for cutting slabs of granite.

29. The saw blade of claim 28, which has a width and said diamond cutting segments have a width, the width of the said diamond cutting segments being greater than the width of said blades.

30. The saw blade of claim 28, wherein said diamond cutting segments are comprised of diamond particles bonded together by a metal or alloy.

31. The saw blade of claim 30, wherein said metal or alloy is one or more of Ni, Cu, Fe, Co, Sn, W, Ti, or an alloy thereof.

32. The saw blade of claim 30, wherein said diamond particles are coated with one or more of Mo, Ti, Cr, or alloys thereof.

33. The saw blade of claim 32, wherein said metal coated diamond particles are overcoated with one or more of Ni, Cu, or alloys thereof.

34. The saw blade of claim 30, wherein said diamond particles range in size from about 15 mesh to 400 mesh.

35. The saw blade of claim 34, wherein said diamond particles range in size from about 25/30 mesh to 70/80 mesh.

36. The saw blade of claim 30, wherein said diamond cutting segments contain between about 10% and 50% by weight of said diamond particles.

37. The saw blade of claim 36, wherein said diamond cutting segments contain between about 10% and 15% by weight of said diamond particles.

38. The saw blade of claim 28, wherein said diamond cutting segments range in size from about 5 to 100 mm in length by 5 to 30 mm in height by 4 to 8 mm in thickness.

39. The saw blade of claim 28, wherein said diamond cutting segments range in spacing from being in edge-to-edge contact to about 400 mm center-to-center.

40. The saw blade of claim 28, wherein said diamond cutting segments are brazed onto the cutting edge of said blades.

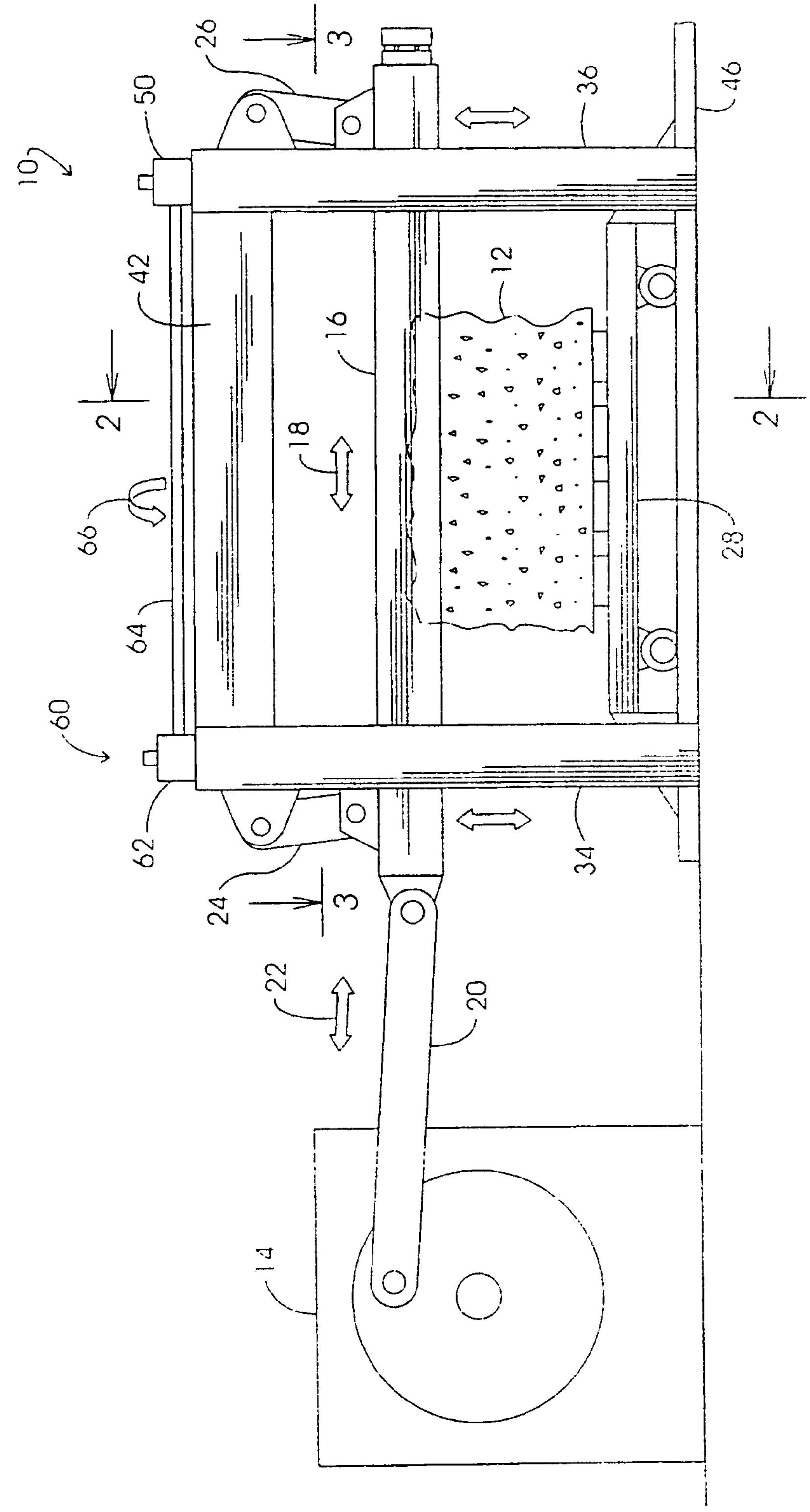

FIG. 1

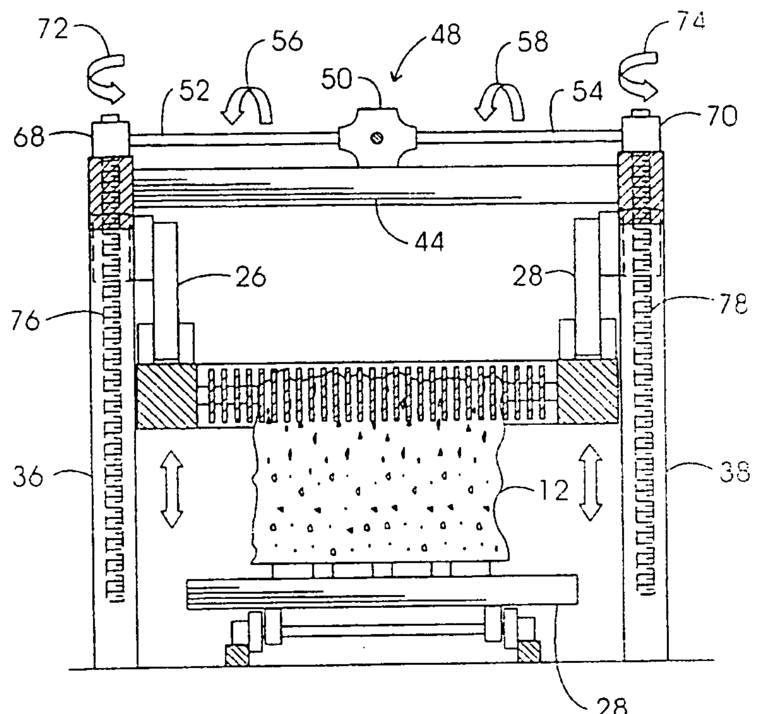
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FIG. 2

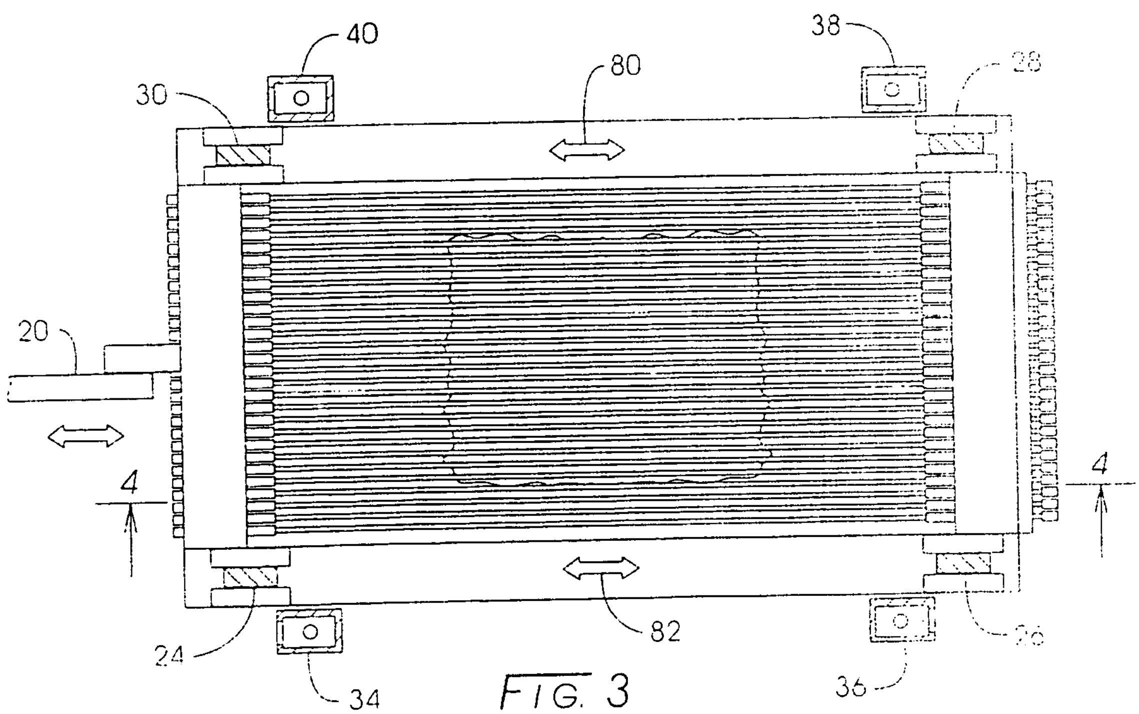
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FIG. 3

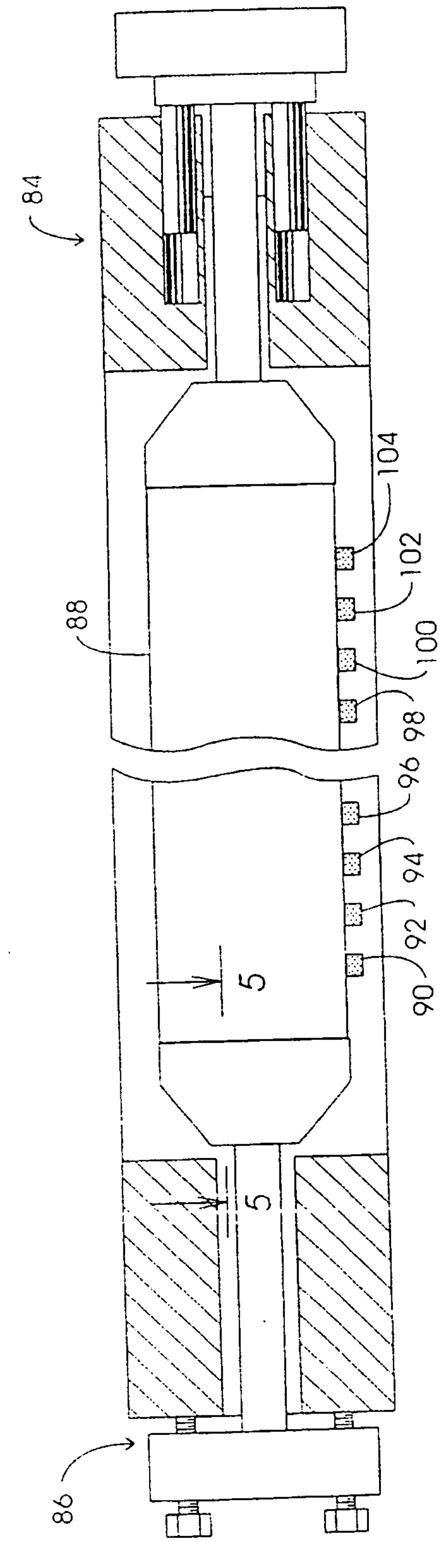

FIG. 4

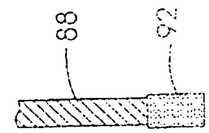

FIG. 7

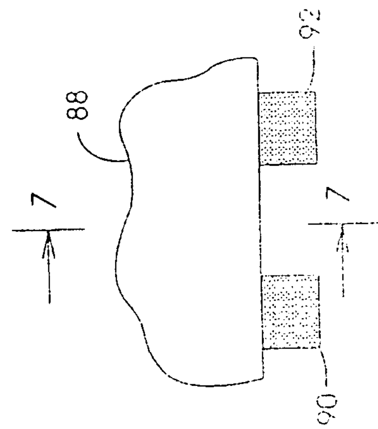

FIG. 6

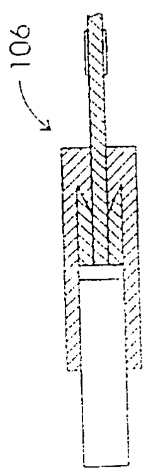

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/16797

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :B28D 1/02
US CL :125/16.01
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 125/12, 13.01, 15, 16.01, 16.02, 17, 19, 21, 23.01, 30.01

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST, WEST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 4,566,427 A (MARECHAL et al) 28 January 1986, See Entire Disclosure.	1 ------ 14 & 28
X ---- Y	US 3,662,734 A (SISLER) 16 May 1972, See Entire Disclosure.	1 ------ 14 & 28
Y	US 5,518,443 A (FISHER) 21 May 1996, See Entire Document.	2-13, 15-27, & 30-40
A	US 5,690,092 A (OGYU) 25 November 1997, See Entire Document.	1-40
Y	US 5,080,085 A (LOVATO) 14 January 1992, See Entire Document.	1 & 2

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search
02 AUGUST 2000

Date of mailing of the international search report
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Form PCT/ISA/210 (second sheet) (July 1998)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/16797

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,181,503 A (FISH et al) 26 January 1993, See Entire Document.	1-40
A	US 2,674,238 A (DESSUREAU et al) 06 April 1954, See Entire Document.	1-40